(NASA-CR-196999) A COMPREHENSIVE INVESTIGATION OF COMET ORIGINS: THE FORMATION OF FLUFFY PLANETESIMALS Final Report (Virginia Univ.) 2 p

N95-70274

Unclas

29/90 0028472

711-82 R

FINAL REPORT

NASA Research Project 5-28392

A Comprehensive Investigation of Comet origins
The Formation of Fluffy Planetesimals

Bertram Donn

It is now accepted that the solar system formed by the accumulation of micron size grains. The recognition that such particles accrete to form irregular, fluffy aggregates opened a new approach to the formation of the solar system. Research carried out under this project was devoted to the study of the formation of planetesimals and cometesimals via fluffy aggregates rather than compact, dense objects.

The first program was an attempt to create fluffy aggregates with cm dimensions in order to study the characteristics of impacts between them. Jeff Beaudry undertook a Master's Thesis to build such objects. Cab-O-Sil, a micrometer powder of fractal-like SiO₂ grains, or glass beads, spherical or milled, were combined in various ways to form cm aggregates. The powders were sintered to porosities of 74 to 92% or bound with wax in various ratios. The Young's modulus and shear strengths were measured. Although very porous aggregates of the proper dimensions were obtained they were not compressible. That was a necessary requirement for coagulating under impact. The more compressible particles could only be obtained in mm sizes, too small for meaningful experiments. It was concluded that porous, compressible aggregates may require a microgravity environment.

Because of the experimental difficulty just described, a theoretical procedure was tried next. This was based on the experiments of Peak and associates who dropped weighted styrofoam balls into three low density powders. They determined the penetration into the dust layer as a function of the kinetic energy per unit area of the projectile. With certain approximations, Donn and Duva (Astrophys. Sp. Sci., 212, 43, 1994) applied these results to developed a theory for impacts between large fluffy, aggregates. This theory was used by another Master's candidate Heather Wood, to calculate the effect of impacts between aggregates with relative velocities appropriate to conditions in the primordial solar nebula. The ratio of penetration to planetesimal size was determined for objects up to 100 meters. For relative velocities of 2 m/s, this ratio was only 20%. Thus, the hypothesis appears plausible.

In her thesis, Ms. Wood computed two evolutionary models. One was a hierarchial sequence starting with 0.1 meter bodies and growing by successive collisions, with the body doubling in mass each time. In this extreme case, 1 km is reached after 41 collisions with very little density increase. In the second model

growth is by successive impacts of the initial 10 cm body on a single growing object. Growth was very slow and it took 500,000 collisions to reach 2.2m when the density increased from an initially adopted 0.2 relative density to 0.6. This is the cutoff density for further growth as the maximum relative density for compaction of grains is about 0.6. The aggregate would no longer be compressible and able to absorb energy, making it behave like a compact solid.

A third, more realistic evolutionary model was devised, intermediate between the first two. Growth is now by random collisions between planetesimals, starting with a uniform distribution of 10 cm aggregates with density of 0.1. A Monte Carlo computational scheme is used to pick two aggregates at random from the distribution. Relative velocity appropriate for the masses are calculated and the penetration determined. volume and density for a uniform cube are obtained and the distribution adjusted for the collision. This procedure is repeated until a density of 0.6 reached when the growth is terminated. Adjustable parameters in the calculation are; initial density, density in compacted zone, constant C, relating energy and penetration. The initial run with C=4000, the experimental value for Cab-0-Sil, had the density increasing at rate which would caused termination at about 300 cm.

Although the grant ran out at this point, calculations were continued. A second trial with $C=10^4$, found for talc, indicated termination at about 400cm. A third trial with $C=10^4 D/D_0$ indicated a maximum size near 1000cm. As the experiments indicated the penetration decreased rather rapidly with increasing density, another run was started with $C=10^4 (D/D_0)^2$ and $D_0=0.07$. In growing from 0.1 to 52cm the density increased from 0.07 only to 0.087. This is a much smaller rate than the previous run and suggests that planetesimals much larger than 1000 cm will be obtained.

The dependence of C on D is not known and neither is the initial density. What we are trying to do is to determine what values of the parameters will yield a size of the order of a km and see if these seem reasonable. Either experiments on impacts of fluffy planetesimals or a theoretical calculation are needed to determine what are reasonable values of the parameters.

DOC #: 28472

ABSTRACT SCREEN

PAGE: 1

** WORDS NOT FOUND *

A comprehensive investigation of comet origins: Th

e formation of fluffy planetesimals

FLUFFY

ABQ: NC

ABA: Derived from text

CIN: SAF KIN: EJS

AIN:

COMETESIMALS

FLUFFY

FLUFFY/AGRGREGATES

The formation of planetesimals and cometesimals via fluffy aggregates rather than compact, dense objects was studied with respect to the formation of the solar system. An attempt was made to create fluffy agrgregates with cm dimensions in order to study the characteristics of impacts between them. Although very porous aggregates of the proper dimensions were obtained, they were not compressible, a necessary requirement for coagulating under impact. It was concluded that porous, compressible aggregates may require a microgravity environment. A theoretical procedure based on dropping weighted styrofoam balls into three low density powders was studied. The results were used to develop a theory for impacts between large fluffy aggragates. This was then used to calculate the effects of impacts between aggregates with relative velocities appropriate to conditions in the primordial solar nebula. Three evolutionary models were then developed.

FLUFFY

PF1=ABA LIST; PF2=RESET; PF3=SIGNON; PF4=RELEASE FROM SUBQ; PF5=SELECTION; PF6=SUBQUEUE; PF7=STORE ABSTRACT; PF8=MAI; PF10=SEND TO 'MAIQ'; PF14=PREVIOUS PAGE; PF15=NEXT PAGE; PF19=TITLE-EXT; PF20=INDEX TERMS

 $A = - \cdot PC \text{ LINE } 11 \text{ COL } 2$

e formation of fluffy planetesimals MAJOR TERMS: SWITCH 1: COMETS 2: PROTOPLANETS 3: AGGREGATES 4: SOLAR SYSTEM EVOLUTION 5: MICROGRAVITY 6: MATHEMATICAL MODELS 7: IMPACT RESISTANCE	DOC NUMB	ER: 28472 INDEXING: SUBJECT/TERMS S	SCREEN	CIN: SAF
MAJOR TERMS: SWITCH 1: COMETS	\mathtt{TITL}		rigins: Th	KIN: EJS
1: COMETS 2: PROTOPLANETS 3: AGGREGATES 4: SOLAR SYSTEM EVOLUTION 5: MICROGRAVITY 6: MATHEMATICAL MODELS 7: IMPACT RESISTANCE		e formation of fluffy planetesimals		AIN:
2: PROTOPLANETS		MAJOR TERMS: SWI	TCH	
2: PROTOPLANETS	1:	COMETS	_	
3: AGGREGATES	2:	PROTOPLANETS	_	
4: SOLAR SYSTEM EVOLUTION	3:	AGGREGATES	_	
5: MICROGRAVITY	4:	SOLAR SYSTEM EVOLUTION	_	
6: MATHEMATICAL MODELS	5:	MICROGRAVITY		
7: IMPACT RESISTANCE	6:	MATHEMATICAL MODELS		
	7:	IMPACT RESISTANCE	_	
8:	8:			
9:	9:		_	
10:	10:		_	
11:	11:			
12:	12:			
13:	13:		_	
14:	14:		_	
15:	15:		_	
MINOR TERMS:		MINOR TERMS:		
1: POROSITY	1:	POROSITY	_	
2: COAGULATION	2:	COAGULATION		
3: STYROFOAM (TRADEMARK)	3:	STYROFOAM (TRADEMARK)		
4: POWDER (PARTICLES)	4:	POWDER (PARTICLES)		
5: PLANETARY EVOLUTION	5:	PLANETARY EVOLUTION		
6: SIZE (DIMENSIONS)	6:	SIZE (DIMENSIONS)		
7:	7:			
8:	8:		_	
9:				
10:	10:			
11:	11:			
12:	12:		_	
13:	13:		_	
14:	14:		_	
15:			_	
PROPOSED TERMS:		PROPOSED TERMS:		
				
PF2=RESET; PF3=SIGNON; PF4=RELEASE; PF5=SELECTION; PF6=SUBQ	PF2=RES	ET: PF3=SIGNON: PF4=RELEASE: PF5=SELECTION:	PF6=SUBO	

PF2=RESET; PF3=SIGNON; PF4=RELEASE; PF5=SELECTION; PF6=SUBQ
PF10=ALPHA; PF11=HIERARCHY; PF12=STORE; PF13=CENTRAL SCREEN; PF20=TITLE/WNF
4B• A =-•PC LINE 6 COL 11